APPENDIX F

EVALUATION REPORT OF GROUND PENETRATING RADAR METHOD

EVALUATION REPORT
OF
GROUND PENETRATING RADAR METHOD

GREENWOOD AREA PEAT STUDY
SEATTLE, WASHINGTON

FOR

SHANNON & WILSON, INC.
SEATTLE, WASHINGTON

JANUARY 2004

PHILIP H. DUOOS
GEOPHYSICAL CONSULTANT

January 9, 2004 Our Ref: 621-03

Mr. Stan Boyle
Shannon & Wilson, Inc.
400 N. 34th St., Suite 300
Seattle, WA 98103

REPORT: Ground Penetrating Radar Evaluation
Lakewood Neighborhood Peat Investigation, Seattle

Dear Mr. Boyle:

This letter summarizes the results of the evaluation of the ground penetrating radar (GPR) at the Greenwood neighborhood project area. Due to the variety of conditions found in peat deposits, this initial evaluation was performed to determine if the GPR method would be effective in delineating the extent of peat deposits in the area. If the GPR method proved effective, the number of additional borings in the Greenwood neighborhood could be minimized. Additionally, if the GPR method provided good results, future studies of other peat deposits in the Seattle area could be performed relying on GPR surveys instead of costly research of existing boring logs in the prospective areas.

SUMMARY

The evaluation summary of the GPR survey was provided to you verbally at your office shortly after the field work was completed. The GPR data seem to provide some information on the edge of the peat deposit in the Greenwood Area. However, the existing boring data were relied upon to a large degree in the interpretation of the GPR data. Interpretation of the GPR data without the existing boring information would have been less straightforward and conclusive. While the GPR data provided an interpretation of the extent of the peat, the thickness of the peat could not be determined. The boring logs indicate that the peat in this area generally contain lenses of silt, clay and fine sand. The silt and clay content in the peat is probably limiting the depth penetration of the GPR signal at this site. Organic peat (with little or no silt or clay) is usually a good medium for the propagation of GPR signals. However, even in organic peat, the GPR signal can be limited in depth if the groundwater contains certain minerals. The effectiveness of the GPR method varies widely from site to site, so it is difficult to determine if the GPR results from the Greenwood area would be typical of other peat deposits in the Seattle area. However, if existing borings from other peat deposits also show a large amount of silt and clay in the peat, the GPR would probably not be effective in determining the thickness of peat.

GPR SURVEY RESULTS

I evaluated a wide range of GPR transducers that included 500 MHz, 200 MHz, and 100 MHz frequencies. A high-power dual 120 MHz transducer was also evaluated. Data were obtained using a GSSI SIR-8 GPR unit and recorded on a thermal graphic recorder. A brief description of the method is attached. One test area was located near the southwest corner of the peat deposit in the parking lot to the south of the Fred Meyer store. The second test area was in an alley that runs north-south near the northwest corner of the peat deposit. The locations of the GPR transects are shown on Figure 1. The transects were marked with white spray paint at 20-foot intervals to provide a reference on the GPR data profiles, and for future boring activities if necessary. Figure 1 also shows the possible edge of the peat deposit based on interpretation of the GPR data.

The top of the peat deposit usually provided a strong reflection on the data. The depth to the top of peat varied from very shallow (less than a foot perhaps) to about 10 feet. No reliable data reflections were observed greater than a couple feet into the peat. What is interpreted to be the base of the peat can be observed near the edge of the peat deposit in many instances. In areas with no peat, depths of about 16 feet were obtained at some locations.

Both the 500 MHz and 200 MHz transducers provided useful and similar information over most of the area. Both delineated the top and edges of the peat. However, the 500 MHz provided a better contrast between the scattered reflections of the overlying fill material and the strong reflection from the top of the peat. The 500 MHz also provided better resolution of the base of the peat near the edge of the deposit. Both the 500 MHz and 200 MHz provided similar maximum depths of penetration (about 16 feet) in the Fred Meyer parking lot outside of the peat deposit. In the alley, the 200 MHz provided similar depth penetration of about 16 feet, while the 500 MHz only penetrated about 10 feet. Although the 500 MHz transducer provided the best overall data at this site, the 200 MHz provided useful information to help confirm the 500 MHz data.

The 100 MHz transducer and the high-power dual 120 MHz transducer did not provide any additional useful depth penetration. The 100 MHz data provided poor definition of the top and edge of the peat deposit because of its poor resolution of the relatively shallow layers. The dual transducer was severely affected by the presence of nearby buildings and powerlines as this transducer is not shielded from such interferences like the other transducers are.

Rough example GPR profiles are attached, with distance noted along the top of the profile and the travel time along the side. A depth scale is not shown because of the different GPR travel times for the overlying fill material (about 6 ns/foot two-way travel time) and the peat (about 18 ns/foot).

RECOMMENDATIONS

The use of the GPR method at this site provided useful information on the edge of the peat deposit when interpreted in conjunction with the existing boring information. The GPR data interpretation would have been more difficult without the existing boring information. However, with any geophysical survey the interpretation results should be confirmed by borings or other means to better characterize the results.

The GPR method was not able to delineate the bottom of the peat deposit, probably due to the loss of GPR signal caused by layers of silt and clay within the peat. Due to the lack of information on the thickness of the peat using the GPR method, it was not deemed suitable for your investigation of the site.

As we discussed, other geophysical methods can often delineate peat. However, the urban environment of the area prohibits the use of many of them. Electromagnetic (EM) induction methods (EM-31 and EM-34 instruments) can provide rapid horizontal delineation of peat deposits as well as a rough estimate on their thickness. However, EM methods are greatly affected by nearby metal objects and powerlines.

Direct current resistivity methods can provide both lateral and vertical information of peat deposits. However, underground pipes, foundations and electrical lines will interfere with the data. The resistivity method also requires driving steel electrodes into the ground (and through pavement). Using the resistivity method over paved surfaces would be time consuming and costly.

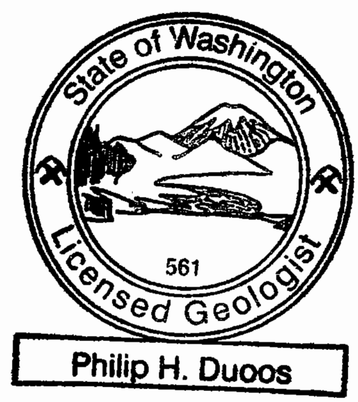
Seismic shearwave reflection methods would probably provide useful information on the horizontal and vertical extent of the peat. The use of a shearwave vibrator allows good seismic data to be obtained in urban environments. A high-resolution survey would be required to minimize the effects of interference from buried utilities and foundations. A seismic survey would provide a high level of detail without the risk of damaging utilities that borings present. However, the cost of such a seismic survey is relatively high compared to other geophysical methods. A high-resolution shearwave seismic survey covering 4800 linear feet (24 transects, each about 200 feet in length) would cost about $80,000.

Although geophysical methods are useful tools in site investigations, the right method must be chosen for the site-specific conditions and objectives. Although the GPR method did not provide sufficient results in the Greenwood area, it may prove useful at other sites.

Please contact me if you have any questions or comments regarding this information, or if you require further assistance. I appreciated the opportunity to work with you on this interesting project.

Sincerely,

Philip H. Duoos
Geophysical Consultant



DESCRIPTION OF GEOPHYSICAL TECHNIQUE

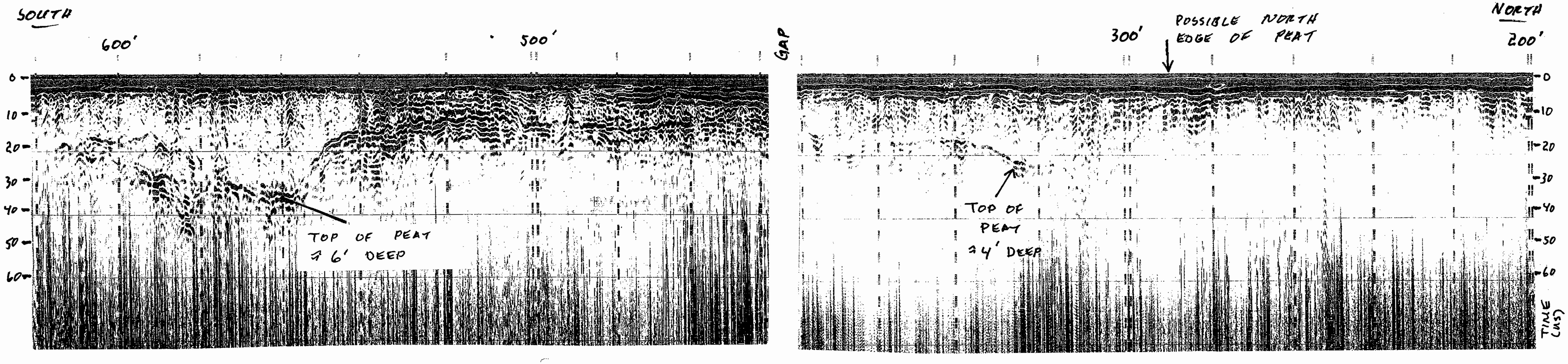
GROUND PENETRATING RADAR

Some of the uses of GPR include locating buried tanks and drums, delineating boundaries of landfills and trenches, and defining voids and geologic stratigraphy. Although other techniques can also provide this information, GPR is less affected by cultural interferences such as overhead powerlines, buildings, and fences. GPR can also provide higher resolution of the target in many cases.

The antenna can either be moved manually by an operator or towed by a vehicle. Depths of exploration can vary widely, from less than a few feet in water-saturated clayey materials to hundreds of feet in glacial ice. A variety of antennas (ranging from 80 to 900 MHz) can be used depending on subsurface conditions and the objective of the survey. Resolution of shallow objects requires higher frequencies, while lower frequencies work better for deeper investigations.

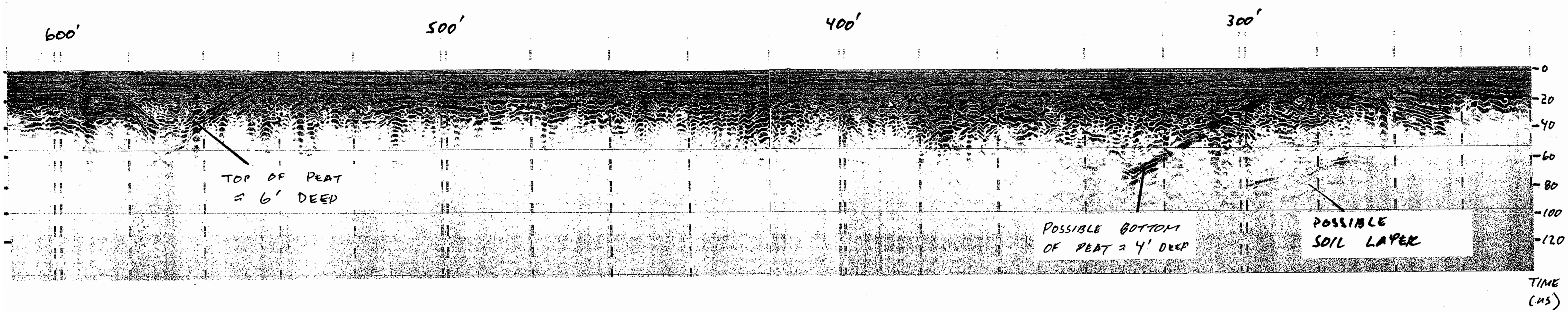
Several factors can affect the effectiveness of the GPR method including reinforced concrete at the surface, the presence of highly conductive materials (such as clays and water), the size, depth, and physical property of the target and; in stratigraphic investigations, the conductivity contrast between stratigraphic units. The presence of numerous buried objects may mask objects and/or stratigraphy below them. The GPR method is most effective in areas with even terrain and free of heavy brush.


Seattle Public Utilities
Greenwood Subsurface Characterization Study
Seattle, Washington
GROUND PENETRATING RADAR
SITE MAP
July 2003
21-1-09915-002
SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
FIG. 1
GROUND PENETRATING RADAR EVALUATION TESTS
GPR SURVEY LINE
POSSIBLE EDGE OF PEAT
Legend
Groundwater Elevation Contour
Limits of Peat
Boring Location
w/ Peat
w/o Peat
and Approximate Cross-section Line
Project Boundary with Designation
Parcel Boundary
Building Outline
Contour - 10 foot interval
Contour - 2 foot interval
Approximate Flow Direction of Shallow Groundwater
0
300
600
900
Feet
NW 92ND ST
NW 90TH ST
N 90TH ST
NW 87TH ST
NW 85TH ST
N 85TH ST
N 87TH ST
3RD AV NW
2ND AV NW
1ST AV NW
GREENWOOD AV N
PHINNEY AV N
PALATINE AV N



500 MHz DATA, WEST SIDE OF ALLEY

0' DISTANCE REFERENCE AT S. EDGE NW 95TH

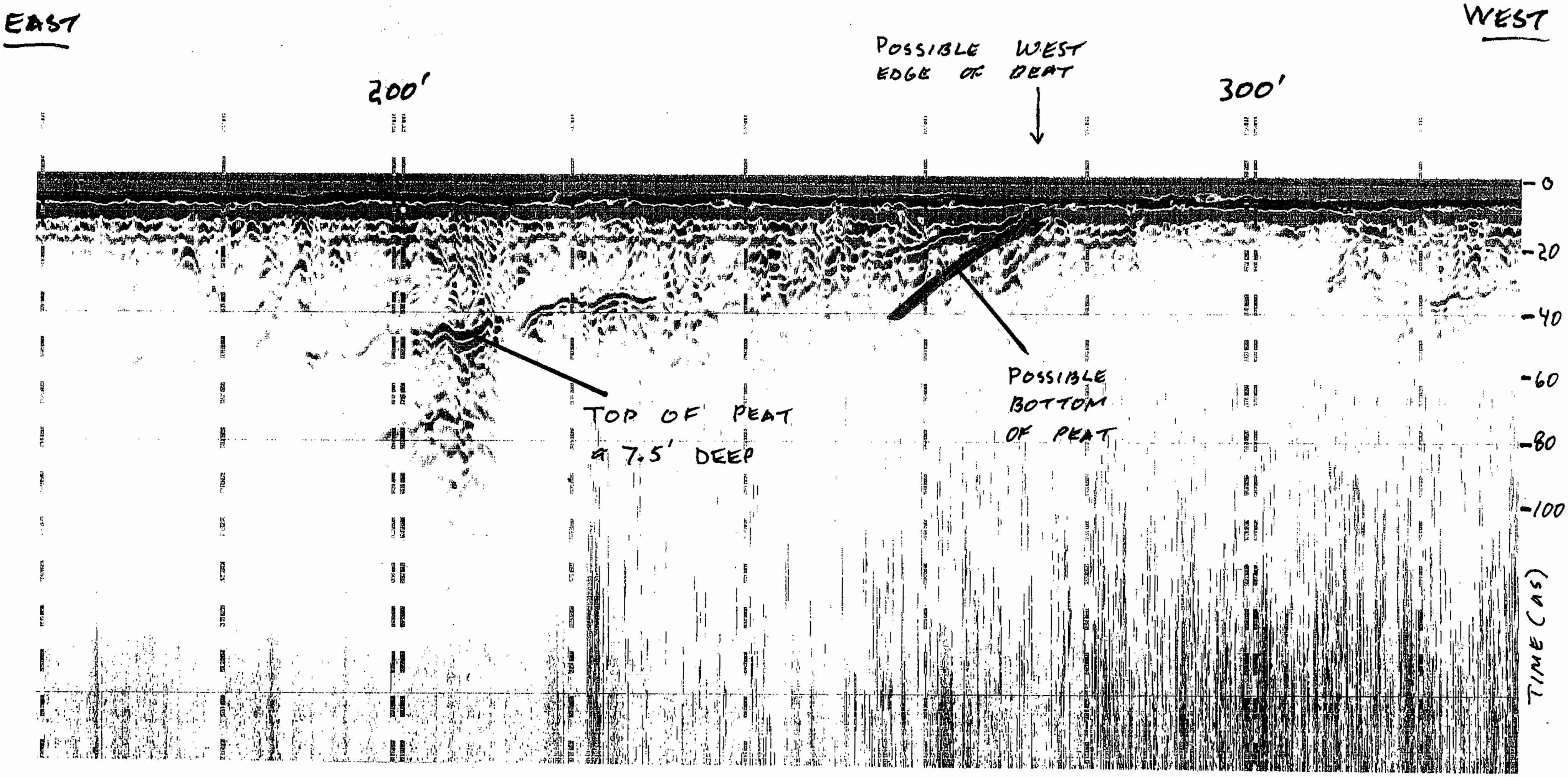


200 MHz DATA, EAST SIDE OF ALLEY

ROUGH GPR PROFILES
NW ALLEY
500 MHz (TOP)
200 MHz (BOTTOM)

P. DUROS 1/9/04

FIG. 2



O' REFERENCE DISTANCE IS EVEN WITH EAST SIDE OF FRED MEYER STORE

ROUGH GPR PROFILE
FRED MEYER AREA
140' S. OF STORE
500 MHZ

P. DUDOS 1/9/0

FIG. 3